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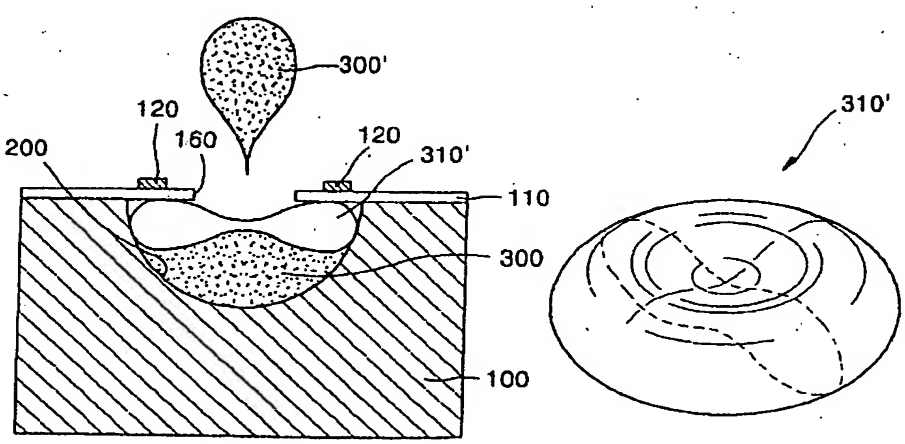
(54) Bubble-jet type ink-jet printhead, manufacturing method thereof, and ink ejection method

(57) A bubble-jet type ink-jet printhead, a manufacturing method thereof, and a method of ejecting ink are provided. In the printhead, a manifold (150) supplying ink, a hemispherical ink chamber (200), and an ink channel (210) for connecting the manifold with the ink chamber are integrally formed on the substrate. A nozzle plate (110) on the substrate (100) having a nozzle, and a heater (120) formed in an annular shape and centered around the nozzle are integrated without a complex process such as bonding. Thus, this simplifies the manufacturing process and facilitates high volume production. Furthermore, according to the ink ejection method, a doughnut-shaped bubble (310) is formed to eject ink, thereby preventing a back flow of ink as well as formation of satellite droplets which may degrade image resolution.

FIG. 10



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Description

[0001] The present invention relates to an ink-jet printhead, and more particularly, to a bubble-jet ink-jet printhead, a manufacturing method thereof, and a method of ejecting ink.

[0002] The ink ejection mechanisms of an ink-jet printer are largely categorized into two types: an electro-thermal transducer type (bubble-jet type) in which a heat source is employed to form a bubble in ink causing ink droplets to be ejected, and an electro-mechanical transducer type in which a piezoelectric crystal bends to change the volume of ink causing ink droplets to be expelled.

[0003] Referring to FIGS. 1A and 1B, a typical bubble-jet type ink ejection mechanism will now be described. When a current pulse is applied to a first heater 12 consisting of resistive heating elements formed in an ink channel 10 where a nozzle 11 is located, heat generated by the first heater 12 boils ink 14 to form a bubble 15 within the ink channel 10, which causes an ink droplet 14' to be ejected.

[0004] Meanwhile, an ink-jet printhead having this bubble-jet type ink ejector needs to meet the following conditions. First, a simplified manufacturing process, low manufacturing cost, and high volume production must be allowed. Second, to produce high quality color images, creation of minute satellite droplets that trail ejected main droplets must be prevented. Third, when ink is ejected from one nozzle or ink refills an ink chamber after ink ejection, cross-talk with adjacent nozzles from which no ink is ejected must be prevented. To this end, a back flow of ink in the opposite direction of a nozzle must be avoided during ink ejection. Another heater 13 shown in FIGS. 1A and 1B is provided for this purpose. Fourth, for a high speed print, a cycle beginning with ink ejection and ending with ink refill must be as short as possible.

[0005] However, the above conditions tend to conflict with one another, and furthermore, the performance of an ink-jet printhead is closely associated with structures of an ink chamber, an ink channel, and a heater, the type of formation and expansion of bubbles, and the relative size of each component.

[0006] In efforts to overcome problems related to the above requirements, ink-jet print heads having a variety of structures have been proposed in U. S. Patent Nos. 4,339,762; 4,882,595; 5,760,804; 4,847,630; and 5,850,241; European Patent No. 317,171, and Fan-Gang Tseng, Chang-Jin Kim, and Chih-Ming Ho, "A Novel Micoinjector with Virtual Chamber Neck", IEEE MEMS '98, pp. 57-62. However, ink-jet printheads proposed in the above patents or literature may satisfy some of the aforementioned requirements but do not completely provide an improved ink-jet printing approach.

[0007] In a first aspect, there is provided a bubble-jet type ink-jet printhead comprising: a substrate having an integrally formed manifold supplying ink, an ink chamber having a substantially hemisph rical shap in which ink to be ejected is filled, an ink channel for supplying ink from the manifold to the ink chamber; a nozzle plate on the substrat , the nozzle plate having a nozzle at a location corresponding to th central part of the ink chamber; a heater formed in the annular shape on the nozzle plate and centered around the nozzle of the nozzle plate; and an electrode, electrically connected to the heater, for applying current to the heater.

[0008] The present invention thus provides an ink-jet printhead including a substrate having an ink supply manifold, an ink chamber, and an ink channel, a nozzle plate having a nozzle, and a heater consisting of r sistive heating elements, and an electrode for applying current to the heater. The manifold supplying ink, the ink chamber filled with ink to be ejected, and the ink chamber for supplying ink from the manifold to the ink chamber may be integrally formed on the substrate. The nozzle plate may be stacked on the substrate, the nozzle plate having the nozzle at a location corresponding to the central part of the ink chamber. The heater may b formed in an annular shape on the nozzle plate and centered around the nozzle of the nozzle plate. The ink chamber is substantially hemispherical. The ink channel may further includes a stopper for reducing the diameter of the ink channel prior to the ink chamber. The present invention thus provides a bubble-jet type ink-jet printhead having a structure that satisfies the above-mentioned requirements.

[0009] Preferably, a bubble formation guide and a nozzle guide, both of which extend down the edges of the nozzle in the depth direction of the ink chamber are formed to guide the direction in which a bubble grows and the shape of the bubble, and the ejection direction of an ink droplet during ink ejection, respectively. The heater is formed in the shape of a horseshoe or omega so that the bubble has a substantially doughnut shape.

[0010] In another aspect, the present invention provides a method of manufacturing a bubble-jet type ink-jet printhead, in which a substrate is etched to form an ink chamber, an ink channel, and ink supply manifold thereon. A nozzle plate is formed on the surface of the substrate, and an annular heater is formed on the nozzle plate. The substrate is etched to form the ink supply manifold. Furthermore, electrodes for applying current to the annular heater are formed. A nozzle plate is etched to form a nozzle having a diameter less than the annular heater on the inside of the annular heater. The substrate exposed by the nozzle is etched to form the substantially hemispherical ink chamber having a diameter greater than the annular heater. The substrate is etched from the surface to form the ink channel for connecting the ink chamber with the manifold.

[0011] Preferably, the ink chamber is formed by anisotropically etching the substrate exposed by the nozzle to a predetermined depth, and isotropically etching the substrate, so that it has a hemispherical shape.

[0012] Pr ferably, in order t form the ink channel, the nozzle plate is tch d from the outside of the annular heater toward the manifold to form a groove for exposing the substrate at the same time that a nozzle plate is tched to form the nozzle. Then, the substrate xpos d by the groove is etched at the same time that the substrate is isotropically etched for forming the ink chamber.

[0013] Preferably, in order to form the ink chamber, the substrate exposed by the nozzle is etched to a predetermined depth to form a trench. Then, a predetermined material layer is deposited over the anisotropically etched substrate to a predetermined thickness and the material layer is anisotropically etched to expose the bottom of the trench and form a spacer of the material layer along the sidewalls of the trench. Then, the substrate exposed to the bottom of the trench is isotropically etched.

[0014] The present invention provides a method of manufacturing the bubble-jet type ink-jet printhead having a structure that satisfies the above-mentioned requirements. The present invention provides a method of ejecting ink in a bubble-jet type ink-jet printhead. According to the ejection method, a bubble having a substantially doughnut shape, the center portion of which opposes the nozzle, is formed within the ink chamber filled with ink. The doughnut-shaped bubble expands and coalesces under the nozzle to cut off the tail of an ejected ink droplet.

[0015] According to the present invention, a bubble is formed in a doughnut shape, which satisfies the above requirements for ink ejection. Furthermore, a simple manufacturing process and high volume production of printheads in chips are allowed.

[0016] The above objectives and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIGS. 1A and 1 B are cross-sections showing the structure of a conventional bubble-jet ink jet printhead along with an ink ejection mechanism;
FIG. 2 is a schematic plan view of a bubble-jet type ink-jet printhead according to the present invention;
FIGS. 3A and 3B are plan views of the unit ink ejector of FIG. 2;
FIGS. 4A and 4B are cross-sections of a printhead according to an embodiment of the present invention, taken along line 4 - 4 of FIG. 3A;
FIGS. 5 and 6 are cross-sections of a printhead according to an embodiment of the present invention, taken along lines 5 - 5 and 6 - 6 of FIG. 3A, respectively;
FIGS. 7 and 8 are cross-sections of a printhead according to another embodiment of the present invention, taken along lines 4 - 4 and 6 - 6 of FIG. 3A, respectively;
FIGS. 9 and 10 are cross-sections showing a m th od of ejecting ink in a bubble-jet type printhead according t an mbodiment of the pres nt invention;
FIGS. 11 and 12 are cross-sections showing a method of ejecting in a bubble-jet type printhead according to an embodiment of the present invention;
FIGS. 13 - 19 are cross-sections showing a process of manufacturing a bubble-jet type ink-jet printhead according to an embodiment of the present invention; and
FIGS. 20 - 22 are cross-sections showing a process of manufacturing a bubble-jet type printhead according to another embodiment of the present invention.

[0017] The present invention will now be described more fully with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art. In the drawings, the shape of elements is exaggerated for clarity, and the same reference numerals appearing in different drawings represent the same element. Further, it will be understood that when a layer is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present.

[0018] Referring to FIG. 2, in a printhead according to the present invention, ink ejectors 3 are arranged in two rows in zig zag along both sides of an ink supply manifold 150 shown with a dotted line. Bonding pads 5, to which wires are bonded, electrically connect to each ink injector 3. Furthermore, the manifold 150 connects with an ink container (now shown) for holding ink. Although the ink ejectors 3 are arranged in two rows as shown in FIG. 2, they may be arranged in one row. In order to achieve high resolution, they may be arranged in three rows. Furthermore, the printhead using a single color of ink is shown in FIG. 2, but three (yellow, magenta and cyan), or four (yellow, magenta, cyan, and black) groups of ink ejectors may be disposed, one group for each color for color printing.

[0019] FIG. 3A is a plan view of the ink ejector which is the feature of present invention. FIGS. 4A, 5 and 6 are cross-sections of a printhead according to the an embodiment of the present invention, taken along lines 4 - 4, 5 - 5, and 6 - 6, respectively. The structure of the printhead according to a first embodiment of the present invention will now be described in detail with reference to FIGS. 3A - 6.

[0020] An ink chamber 200 for containing ink, which has a substantially hemispherical shape, is formed on the surface of a substrate 100, and an ink channel 210 for supplying ink to the ink chamber 200 is formed shallower than the ink chamber 200. The manifold 150 for connecting to the ink channel 210 and thus supplying

ink to the ink channel 210 is formed on the rear surface of the substrat 100. Furthermore, a bubble barri r 205 (FIG. 8), which prevents a bubble from being pushed back into the ink channel 210 when the bubble expands, projects out slightly toward the surface of th substrate 100 at a point where th ink chamber 200 and th ink channel 210 meet each other. Here, the substrate 100 is preferably made out of a silicon having the same crystal orientation [100] as is widely used in manufacturing an integrated circuit.

[0021] A nozzle 160 and a nozzle plate 110, in which a groove 170 for an ink channel is formed, are formed on the substrate 100, thus forming an upper wall of the ink chamber 200 and the ink channel 210. If the substrate 100 is formed of a silicon, the nozzle plate 110 may be formed of a silicon oxide layer formed by the oxidation of the silicon substrate 100 or a silicon nitride layer deposited on the silicon substrate 100.

[0022] A heater 120 having an annular shape for forming a bubble is disposed on the nozzle plate 110 so as to surround the nozzle 160. As shown in FIG. 3A, the heater 120 consisting of resistive heating elements such as polycrystalline silicon has an approximately omega or horseshoe shape combined with electrodes 180 which is typically made of metal for applying a current pulse to the heater 120. The heater 120 and the electrodes 180 are electrically connected by contacts 185. Also, the electrodes 180 are connected to the bonding pad (5 of FIG. 2).

[0023] Meanwhile, FIGS. 3B and 4B are a plan view and a cross-section taken along line 4 - 4 of FIG. 3A, respectively, which show an modified example of this embodiment. Referring to FIG. 3B, a heater 120' has a circular shape and is connected to the electrodes 180 by the contacts 185 at approximately symmetrical locations.

[0024] Referring to FIG. 4B, the heater 120 is disposed beneath a nozzle plate 110' so as to contact ink that fills the ink chamber 200.

[0025] FIGS. 7 and 8 are cross-sections taken along lines 4 - 4 and 6 - 6 of FIG. 3A, respectively, which show the structure of a printhead according to a second embodiment of the present invention. Referring to FIGS. 3A, 7 and 8, although the printhead according to this embodiment has a basically similar structure to the first embodiment, it differs from the first embodiment in the structures of an ink chamber 200' and a nozzle 160'. That is, the bottom of the ink chamber 200' is substantially hemispherical like the ink chamber 200 of the first embodiment, but a droplet guide 230 and a bubble guide 203 are disposed at an upper portion of the ink chamber 200'. The droplet guide 230 extends down the edge of the nozzle 160' toward the ink chamber 200', and the bubble guide 203 is formed under the nozzle plate 110, which forms the upper wall of the ink chamber 200', with a substrate material remaining along the inner surface of the droplet guide 230. The functions of the droplet guide 230 and the bubbl guide 203 will be described below.

[0026] The functions and effects of th ink-jet printheads according to the first and second embodiments of the present invention will now be described together with a method of ejecting ink according to the present invention.

[0027] FIGS. 9 and 10 show the ink ejection mechanism for the printhead according to the first embodiment of the present invention. As shown in FIG. 9, if a current pulse is applied to the annular heater 120 when the ink chamber 200 is filled with ink 300 supplied through the manifold 150 and the ink channel 210 by capillary action, then heat generated by the heater 120 is transmitt d through the underlying nozzle plate 110, which boils the ink 300 under the heater 120 to form bubbles 310. The bubbles 310 have an approximately doughnut shape conforming to the annular heater 120 as shown at the right side of FIG. 9.

[0028] If the doughnut-shaped bubbles 310 expand with the lapse of time, as shown in FIG. 10, the bubbles 310 coalesces below the nozzle 160 to form a substantially disk-shaped bubble 310', the center portion of which is concave. At the same time, the expanding bubble 310' causes ink 300' within the ink chamber 200 to be ejected. If the applied current cuts off, the heater 120 is cooled to shrink or collapse the bubble 310', and th n the ink 300 refills the ink chamber 200.

[0029] In the ink ejection mechanism according to this embodiment, the doughnut-shaped bubbles 310 coalesce to cut off the tail of the ejected ink 300', thus preventing the formation of the satellite droplets. Furthermore, the expansion of the bubble 310 or 310' is limited within the ink chamber 200, which prevents a back flow of the ink 300, so that cross-talk between adjacent ink ejectors does not occur. Furthermore, since the ink channel 210 is shallower and smaller than the ink chamber and the bubble barrier 205 is formed at the point where the ink chamber 200 and the ink channel 210 meet each other, as shown in FIG. 6, it is very effective in preventing the bubble itself 310 or 310' from being pushed toward the ink channel 210.

[0030] Meanwhile, the area of the annular heater 120 is so wide as to be rapidly heated and cooled, which quickens a cycle beginning with the formation of the bubble 310 or 310' ending with the collapse, thereby allowing for a quick response rate and high driving frequency. Furthermore, since the ink chamber 200 is hemispherical, a path along which the bubbles 310 and 310' expand is more stable compared to a conventional ink chamber having the shape of a rectangular solid or a pyramid, and the formation and expansion of a bubble are quickly made thus ejecting ink within a relatively short time.

[0031] FIGS. 11 and 12 shows an ink ejection mechanism for the printhead according to the second embodiment of the invention. The difference from the ink ejection method for the printhead according to the first embodiment will now be described.

[0032] First, since bubbles 310" expands downward by the bubble guid 203 n ar the nozzle 160', there is little possibility that the bubbles 310" will coalesce below the nozzle 160'. However, the possibility that the expanding bubbles 300" will merge und r the nozzle 160 may be controlled by controlling the length by which the droplet guide 230 and the bubble guide 203 extend downward. The ejection direction of the ejected droplet 300' is guided by the droplet guide 230 extending down the edges of the nozzle 240 so that the direction is exactly perpendicular to the substrate 100.

[0033] Next, a method of manufacturing an ink-jet printhead according to the present invention will now be described. FIGS. 13 - 19 are cross-sections showing a method of manufacturing the printhead according to the present invention. The left and right sides of the drawings are cross-sections taken along lines 4 - 4 and 6 - 6 of FIG. 3A, respectively. The same is true of FIGS. 20 - 22.

[0034] First, the substrate 100 is prepared. A silicon substrate having a crystal orientation of [100] and having a thickness of about 500 μm is used as the substrate 100 in this embodiment. This is because the use of a silicon wafer widely used in the manufacture of semiconductor devices allows for high volume production. Next, if the silicon wafer is wet or dry oxidized in an oxidation furnace, as shown in FIG. 13, the front and rear surfaces of the silicon substrate 100 are oxidized, thereby allowing silicon oxide layers 110 and 115 to grow. A very small portion of the silicon wafer is shown in FIG. 13, and a printhead according to this invention is fabricated by tens to hundreds of chips on a single wafer. That is, FIGS. 13 shows only the unit ink ejector 3 in the chip as shown in FIG. 2. Furthermore, as shown in FIG. 13, the silicon oxide layers 110 and 115 are developed on both front and rear surfaces of the substrate 100. This is because a batch type oxidation furnace exposed to an oxidation atmosphere is used on the rear surface of the silicon wafer as well. However, if a single wafer type oxidation apparatus exposing only a front surface of a wafer is used, the silicon oxide layer 112 is not formed on the rear surface of the substrate 100. The fact that a predetermined material layer is formed on a front or rear surface of the substrate 100 depending on the type of an oxidation apparatus is true of FIGS. 20 - 22. For convenience's sake, it will now be shown that a different material layer such a polycrystalline silicon layer, a silicon nitride layer and a tetraethyleorthosilicate (TEOS) oxide layer as will be described below is formed only on the front surface of the substrate 100.

[0035] FIG. 14 shows a state in which the annular heater 120 has been formed. The annular heater 120 is formed by depositing polycrystalline silicon over the silicon oxide layer 110 and patterning the polycrystalline silicon layer in the form of annulus. Specifically, the polycrystalline silicon may be deposited to a thickness of about 0.8 μm by means of low pressure chemical vapor deposition (CVD). The polycrystalline silicon layer is patt rned by photolithography using a photo mask and photor sist and an etching process of tching th polycrystalline silicon layer deposited over the silicon oxide layer 100 using a photoresist pattern as an etch mask.

[0036] FIG. 15 shows a state in which a silicon nitrid layer 130 and a TEOS oxide layer 140 have been sequentially formed over the resulting material shown in FIG. 14. The silicon nitride layer 130 may also be deposited to a thickness of about 0.5 μm by low pressur CVD as a protective layer of the annular heater 120, while the TEOS oxide layer 140 may be deposited to a thickness of about 1 μm by CVD.

[0037] FIG. 16 shows a state in which the ink supply manifold 150 has been formed. The manifold 150 is formed by obliquely etching the rear surface of the wafer. More specifically, an etch mask that limits a region to be etched is formed on the rear surface of the wafer, and wet etching is performed for a predetermined period of time using tetramethyl ammonium hydroxide (TMAH) as an etchant. Then, etching in a crystal orientation of [111] is slower than etching in other orientations to form the manifold 150 with a side surface inclined at 54.7 degrees.

[0038] Although it has been described though FIG. 16 that the manifold 150 is formed by obliquely etching the rear surface of the substrate 100, the manifold 150 may be formed by anisotropic etching, penetrating and etching the substrate 100, or etching the front surface of the substrate 100.

[0039] Referring to FIG. 17, the TEOS oxide layer 140, the silicon nitride layer 130, and the silicon oxide layer 110 are sequentially etched to form an opening 160 exposing the substrate 100 with a diameter less than that of the annular heater 130 on the inside of the annular heater 120. At the same time, the opening 170 (FIG. 19) is formed on the outside of the annular heater 120 in a straight line up to the upper portion of the manifold 150. The opening 170 is a groove which will be used in etching the substrate 100 for forming an ink channel. Also, the opening 170 has a length of about 50 μm and a width of about 2 μm.

[0040] Meanwhile, to form the electrodes (180 of FIG. 3) for applying current to the annular heater 120 and the contacts 185 for electrically connecting the annular heater 120 with the electrodes 180, first, the TEOS oxide layer 140 and the silicon nitride layer 130 deposited on a portion where the contacts 185 will be formed are removed to expose a portion of the annular heater 120. Then, a conductive metal such as aluminum is deposited over the resulting structure to a thickness of about 1 μm. Copper may be used as the electrodes 180 by electroplating.

[0041] FIG. 18 shows a state in which the substrate exposed by the opening 160 is etched to a predetermined depth to form a trench 190. In this case, the substrat 100 exposed by the opening 170 is not etched. Mor specifically, aft r an etch mask such as a photoresist layer PR that exposes only the opening 160 is

formed on the substrate 100, the silicon substrate 100 is etched by means of dry etching using inductively coupled plasma or reactive ion etching.

[0042] FIG. 19 shows a structure obtained by removing the photoresist layer PR by m ans of ashing and strip in th state shown in FIG. 18 and is tr pically etching the exposed silicon substrate 100. More specifically, the substrate 100 is etched for a predetermined period of time using XeF_2 as an etch gas. Then, as shown in FIG. 19, the substantially hemispherical ink chamber 200 is formed with depth and radius of about 20 µm, and the ink channel 210 for connecting the ink chamber 200 with the manifold 150 is formed with depth and radius of about 8 µm. Also, the projecting bubble barrier 205 is formed by etching at the point where the ink chamber 200 and the ink channel 210 meet each other. In this way, the printhead according to the first embodiment of the present invention is completed.

[0043] Meanwhile, only the substrate 100 exposed by the opening 160 is etched as shown in FIG. 18 so as to limit a doughnut-shaped bubble within the ink chamber 200 by making the depth of the ink chamber 200 deeper than that of the ink channel 210 as shown in FIG. 19. However, since an etch rate varies due to the difference in the width of the openings 160 and 170 during isotropic etching shown in FIG. 19, the ink chamber 200 and the ink channel 210 are formed to have different depths. Thus, the step shown in FIG. 18 may be omitted.

[0044] Furthermore, the printhead having a structure in which the heater 120 is disposed beneath the nozzle plate 110' as shown in FIG. 4B may be manufactured by etching and removing the silicon oxide layer 110 exposed to the ink chamber 200 in a state shown in FIG. 19. The thus-exposed heater 120 directly contacts ink. To prevent attachment of ink, a silicon oxide layer or a silicon nitride layer may be deposited thinly over the exposed heater 120 as a protective layer.

[0045] FIGS. 20 - 22 are cross-sections showing a method of manufacturing the printhead according to the second embodiment of the present invention. The manufacturing method according to this embodiment is the same as the first embodiment up to the step shown in FIG. 18, and the method according to this embodiment may further include the steps shown in FIGS. 20 and 21.

[0046] That is, as shown in FIG. 20, the photoresist layer PR is removed in a state shown in FIG. 18 and then a predetermined material layer such as a TEOS oxide layer 220 is deposited over the resulting material to a thickness of about 1 µm. Subsequently, the TEOS oxide layer 220 is anisotropically etched so that the silicon substrate 100 is exposed to form spacers 230 and 240 along sidewalls of the trench 190 and the opening 170, respectively, as shown in FIG. 21. Th exposed silicon substrate 100 is isotropically etched in a state shown in FIG. 21 like in the first embodiment, thus completing the printhead according to the second embodiment of the pres nt invention.

[0047] Although this invention has been described with ref rence to pr ferred embodiments th reof, it will be und rstood by thos skill d in the art that various changes in form and details may be made therein. For example, materials forming the elements of the printhead according to this invention may not be limited to illustrated ones. That is, the substrate 100 may b formed of a material having good processibility, which is other than silicon, and the same is true of the heater 120, the electrode 180, a silicon oxide layer, or a nitride layer. Furthermore, the stacking and formation method for each material layer are only examples, and thus a variety of deposition and etching techniques may be adopted.

[0048] Also, the sequence of processes in a method of manufacturing a printhead according to this invention may differ. For example, etching the rear surface of the substrate 100 for forming the manifold 150 may be performed before the step shown in FIG. 15 or after th step shown in FIG. 17, that is, the step of forming the nozzle 160. Furthermore, the step of forming the electrodes 180 may be performed before the step shown in FIG. 17.

[0049] Along therewith, specific numeric values illustrated in each step may be adjustable within a range in which the manufactured printhead can operate normally.

[0050] As described above, according to this invention, the bubble is doughnut-shaped thereby preventing a back flow of ink and cross-talk between adjacent ink ejectors. The ink chamber is hemispherical; the ink channel is shallower than the ink chamber, and the bubble barrier projects at the connection portion of the ink chamber and the ink channel, thereby also preventing a back flow of ink.

[0051] The shape of the ink chamber, the ink channel, and the heater in the printhead according to this invention provides a high response rate and high driving frequency. Furthermore, the doughnut-shaped bubble coalesces at the center, which prevents the formation of satellite droplets.

[0052] Meanwhile, the printhead according to the second embodiment of the invention allows the droplets to be ejected exactly in a direction perpendicular to the substrate by forming the bubble guide and the droplet guide on the edges of the nozzle.

[0053] Furthermore, according to a conventional printhead manufacturing method, a nozzle plate, an ink chamber, and an ink channel are manufactured separately and bonded to each other. However, a method of manufacturing a printhead according to this invention involves integrating the nozzle plate and the annular heater with the substrate on which the ink chamber and the ink channel are formed, thereby simplifying a fabricating process compared with the conventional manufacturing method. Furthermore, this prevents occurrences of misalignment.

[0054] In addition, the manufacturing method according to this invention is compatible with a typical manufacturing process for a semiconductor device, thereby

facilitating high volume production.

Claims

1. A bubble-jet type ink-jet printhead comprising:

   a substrate having an integrally formed manifold supplying ink, an ink chamber having a substantially hemispherical shape in which ink to be ejected is filled, an ink channel for supplying ink from the manifold to the ink chamber;
   a nozzle plate on the substrate, the nozzle plate having a nozzle at a location corresponding to the central part of the ink chamber;
   a heater formed in the annular shape on the nozzle plate and centered around the nozzle of the nozzle plate; and
   an electrode, electrically connected to the heater, for applying current to the heater.

2. The printhead of claim 1, wherein a depth of the ink chamber is greater than a depth of the ink channel.

3. The printhead of claim 1 or 2, the ink channel further comprising a stopper for reducing the diameter of the ink channel prior to the ink chamber.

4. The printhead of any preceding claim, further comprising a nozzle guide within the ink chamber adjacent to the nozzle of the nozzle plate and perpendicular to the nozzle plate.

5. The printhead of any preceding claim, wherein the heater is formed in the shape of a horseshoe.

6. The printhead of any preceding claim, wherein the heater is formed in a round shape.

7. The printhead of any preceding claim, wherein the substrate is formed of silicon wherein the crystal direction is diagonal to the nozzle plate.

8. The printhead of any preceding claim, wherein the heater is formed of polycrystalline silicon.

9. The printhead of any preceding claim, further comprising a curved bubble formation guide in the ink chamber and adjacent to the heater.

10. A method of manufacturing a bubble-jet type ink-jet printhead, the method comprising the steps of:

    forming a nozzle plate on the surface of a substrate;
    forming an annular heater on the nozzle plate;
    etching the substrate and forming a manifold for supplying ink;
    forming electrod s el ctrically conn cted to th annular heat r on th nozzle plate;
    etching the nozzle plate and forming a nozzle having a diameter less than the annular heater n th inside of the annular heat r;
    etching the substrate exposed by the nozzl and forming a substantially hemispherical ink chamber having a diameter greater than the annular heater; and
    etching the substrate between the manifold and the ink chamber from the surface an forming an ink channel for connecting the ink chamber with the manifold.

11. The method of claim 10, wherein forming the ink chamber comprises the steps of:

    anisotropically etching the substrate exposed by the nozzle to a predetermined depth; and
    isotropically etching the substrate after anisotropically etching the substrate.

12. The method of claim 10, wherein forming the ink channel comprises the steps of:

    etching the nozzle plate from the outside of the annular heater toward the manifold and forming a groove for exposing the substrate; and
    isotropically etching the substrate exposed by the groove.

13. The method of any of claims 10 to 12, wherein the steps of forming the ink chamber and the ink channel are performed at the same time.

14. The method of claim 10, wherein forming the ink chamber comprises the steps of:

    anisotropically etching the substrate exposed by the nozzle to a predetermined depth to form a trench;
    depositing a predetermined material layer over the anisotropically etched substrate to a predetermined thickness;
    anisotropically and partially etching the material layer to expose the bottom of the trench and forming a spacer of the material layer along the sidewalls of the trench; and
    isotropically etching the substrate exposed to the bottom of the trench.

15. The method of any of claims 10 to 14, wherein the heater is omega-shaped.

16. The method of any of claims 10 to 15, wherein the heater is circular.

17. The method of any of claims 10 to 16, wherein the

substrate is formed of silicon having a crystal ori n-tation of [100].

18. The method of claim 17, wherein, in the step of forming the nozzle plat , the nozzle plate is form d of a silicon oxide layer formed by oxidating the surface of the silicon substrate.

19. The method of any of claims 10 to 18, wherein the heater is formed of polycrystalline silicon.

20. A method of ejecting ink in a bubble-jet type ink-jet printhead having a nozzel, wherein a bubble having a substantially doughnut shape, the center portion of which opposes the nozzle, is formed within the ink chamber filled with ink.

21. The method of claim 20, wherein the doughnut-shaped bubble expands and coalesces under the nozzle to cut off the tail of an ejected ink droplet.

FIG. 1A (PRIOR ART)

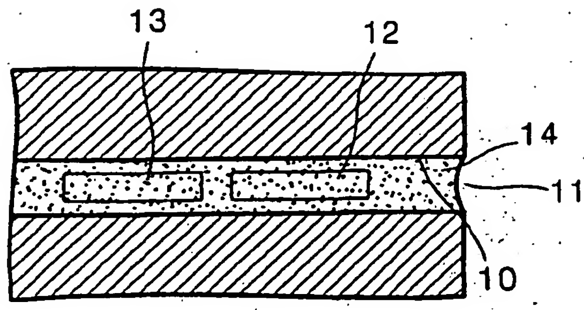

FIG. 1B (PRIOR ART)

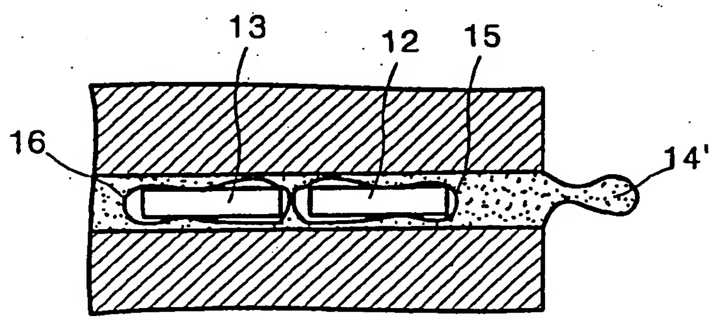

FIG. 2

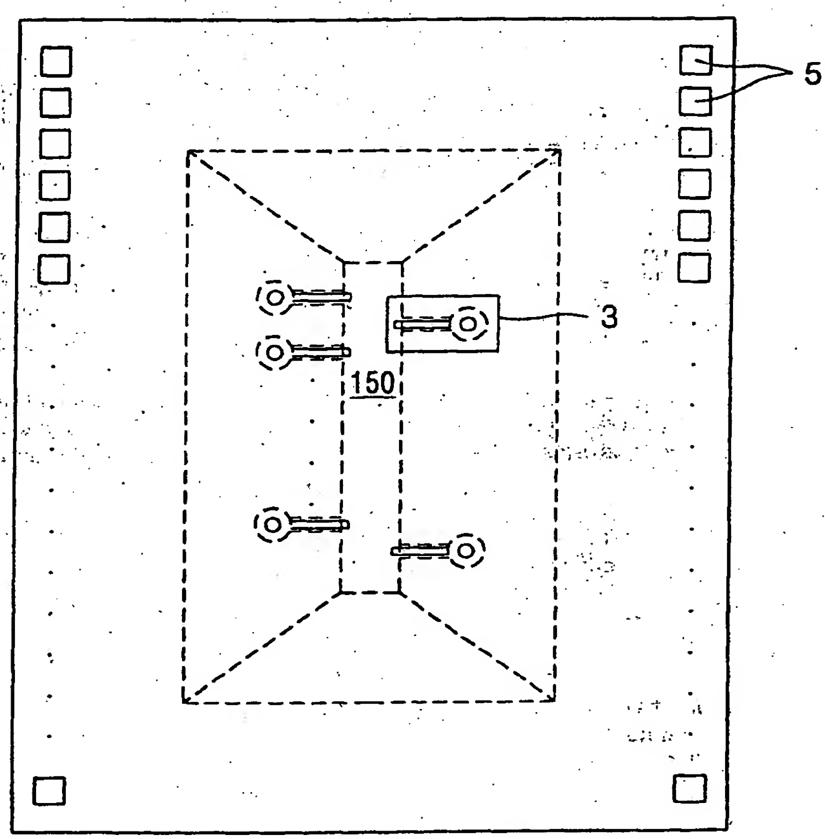

FIG. 3A

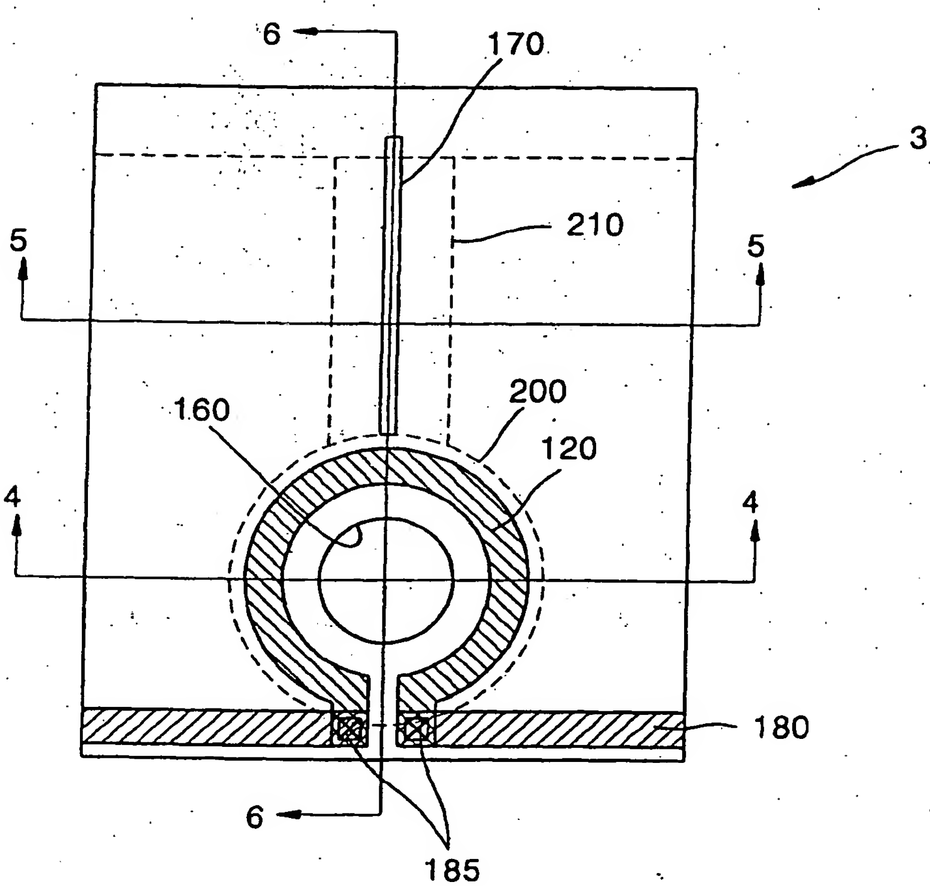

FIG. 3B

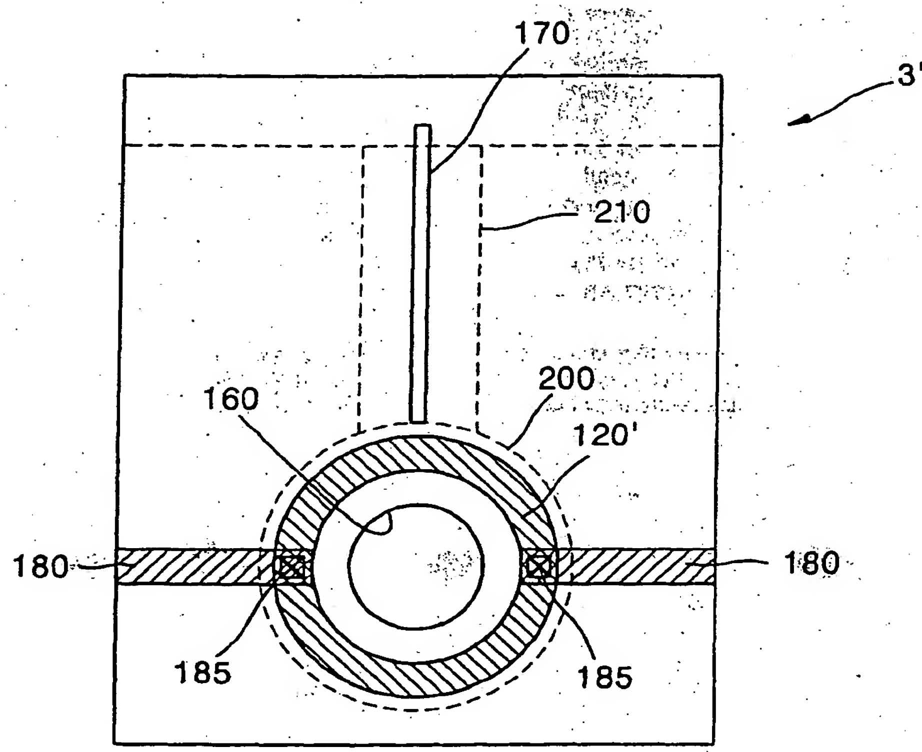

FIG. 4A

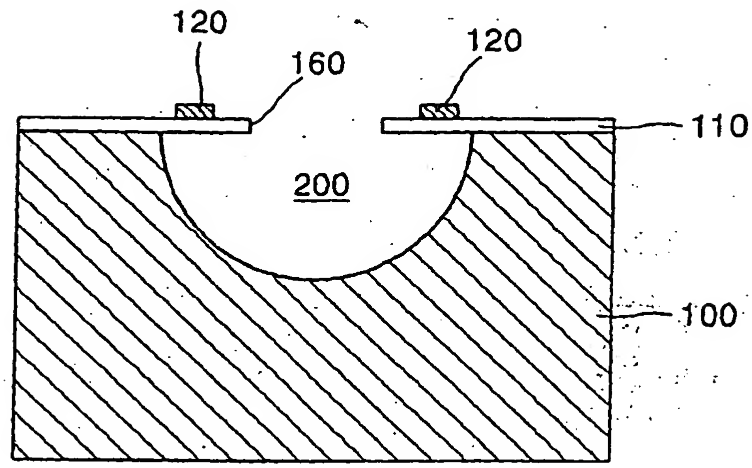

FIG. 4B

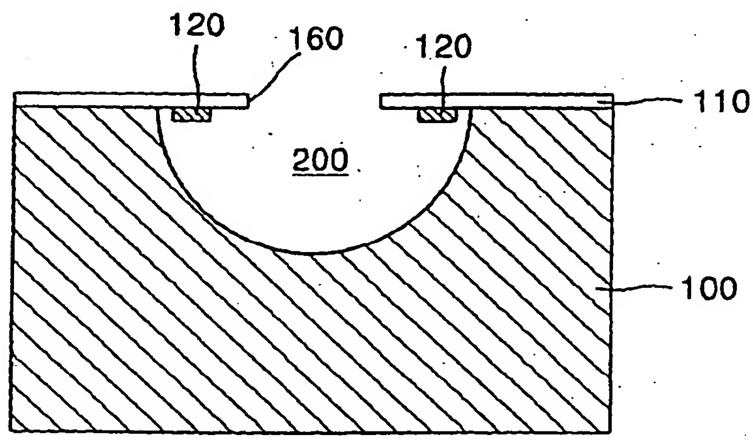

FIG. 5

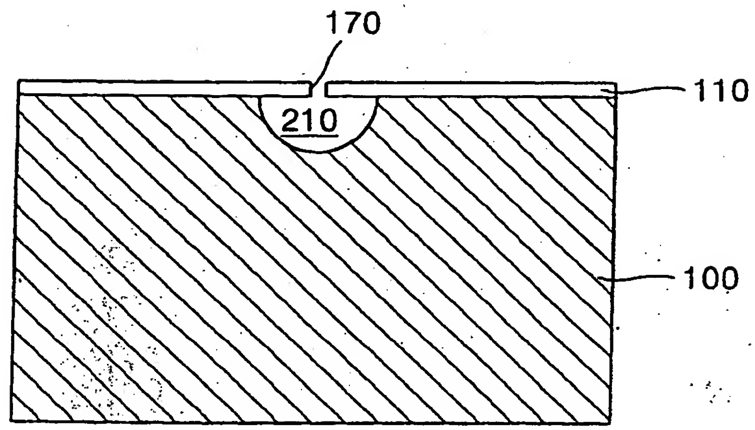

FIG. 6

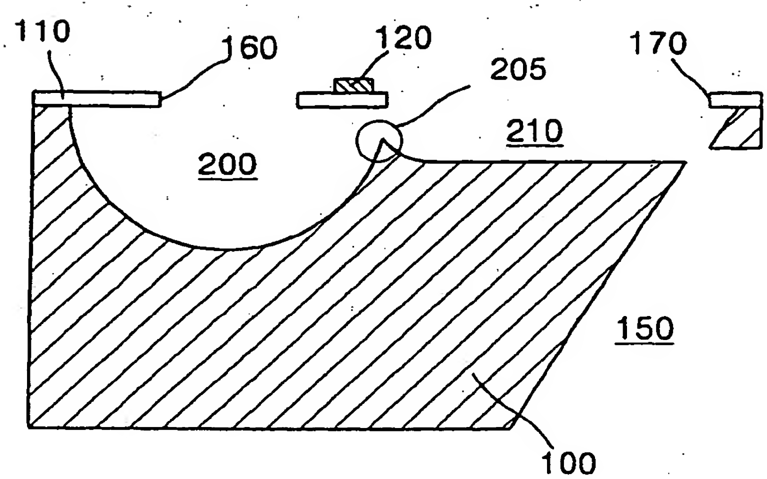

FIG. 7

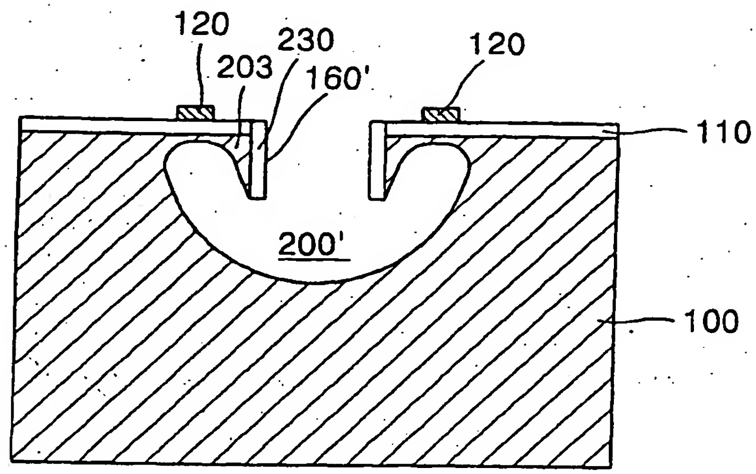
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FIG. 8

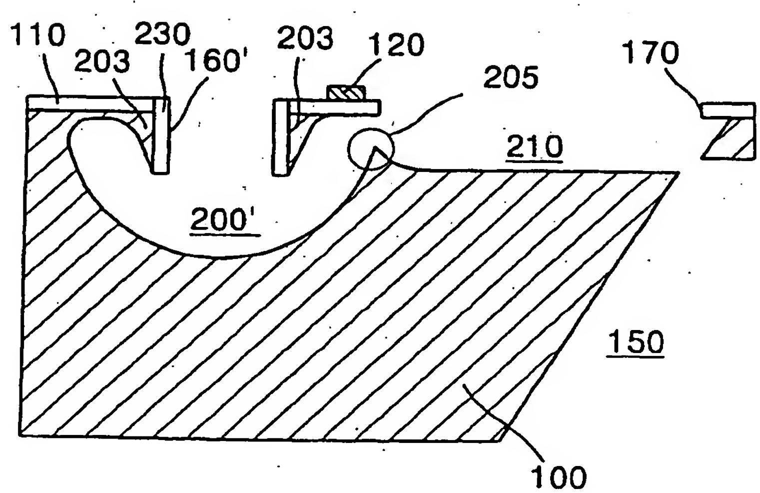
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FIG. 9

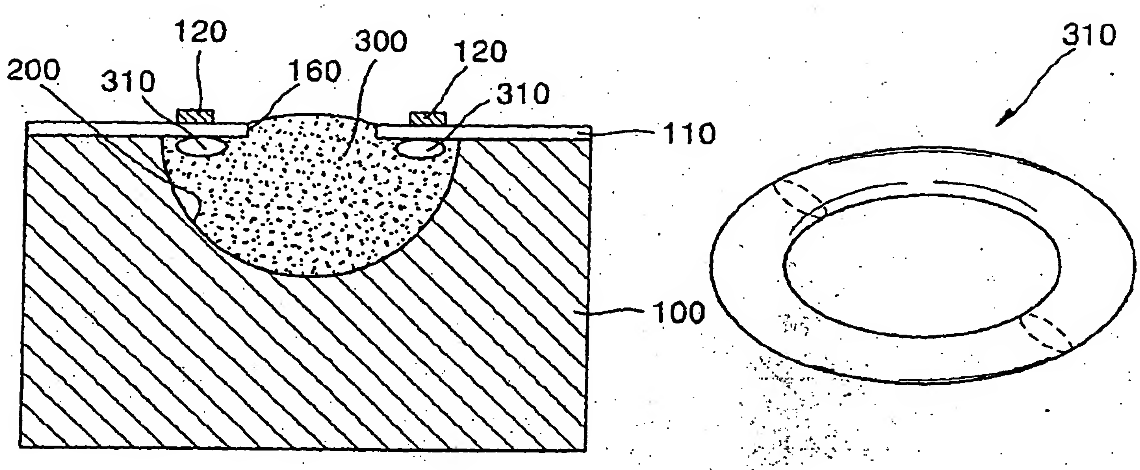
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FIG. 10

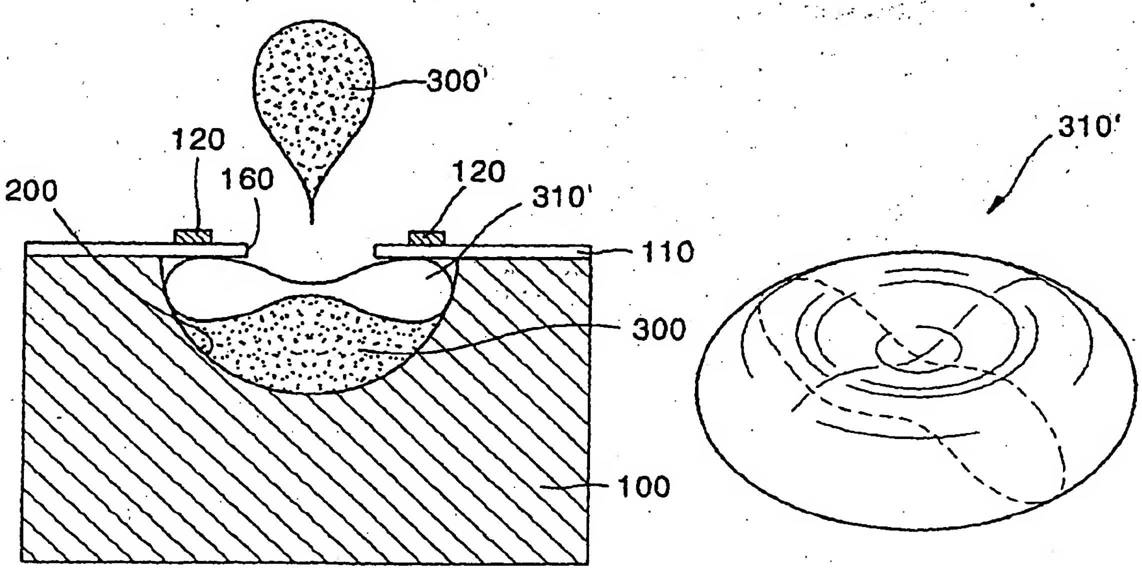
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FIG. 11

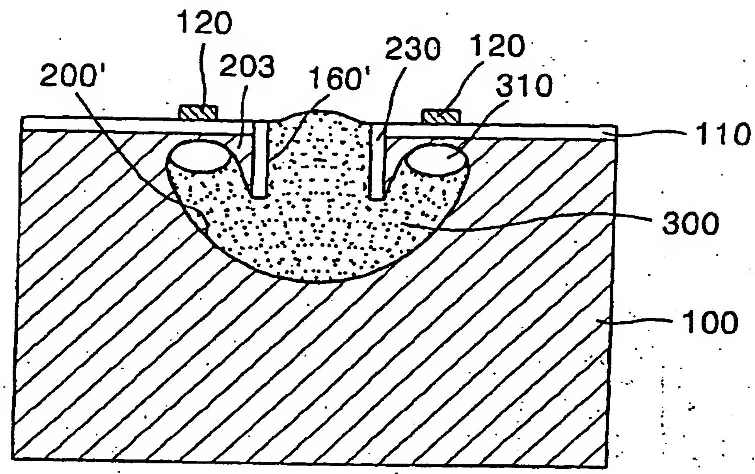
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FIG. 12

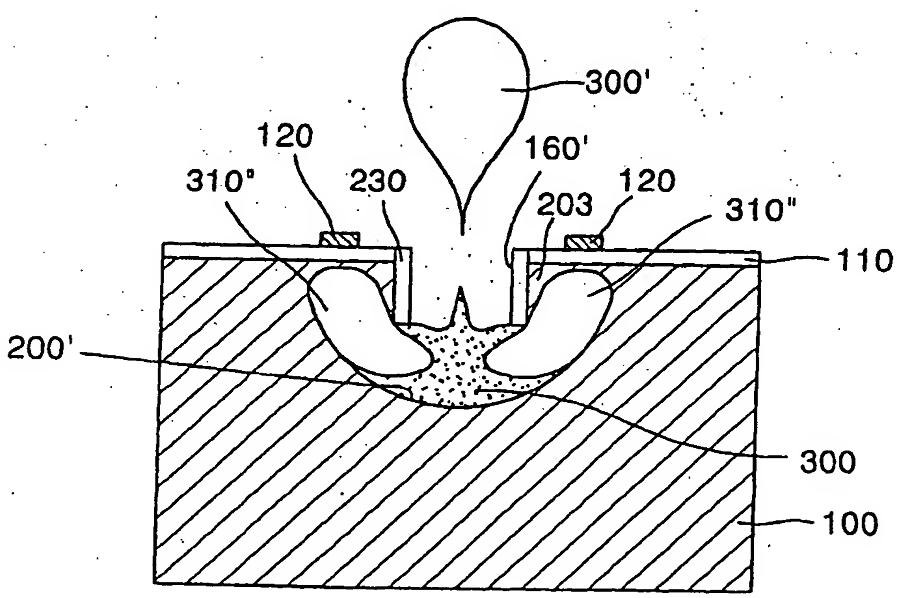
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FIG. 13

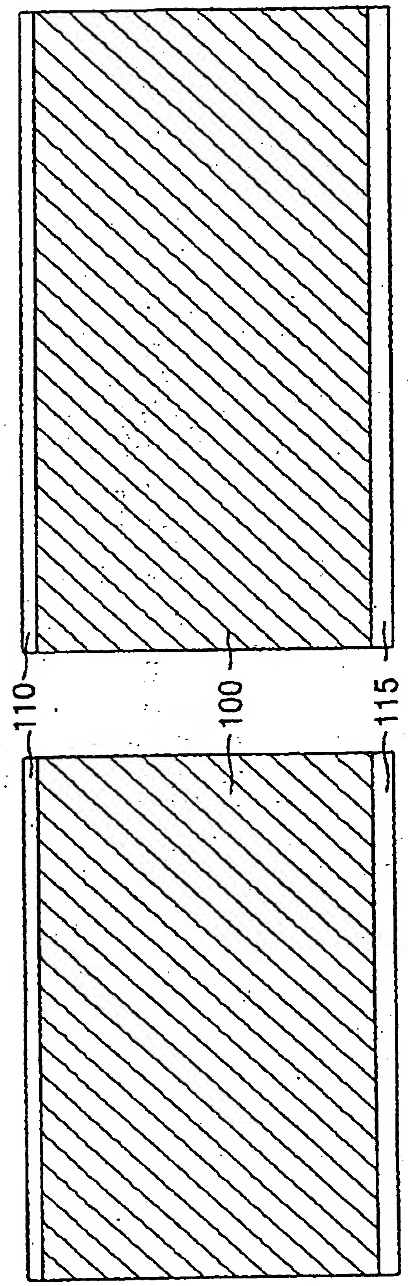

FIG. 14

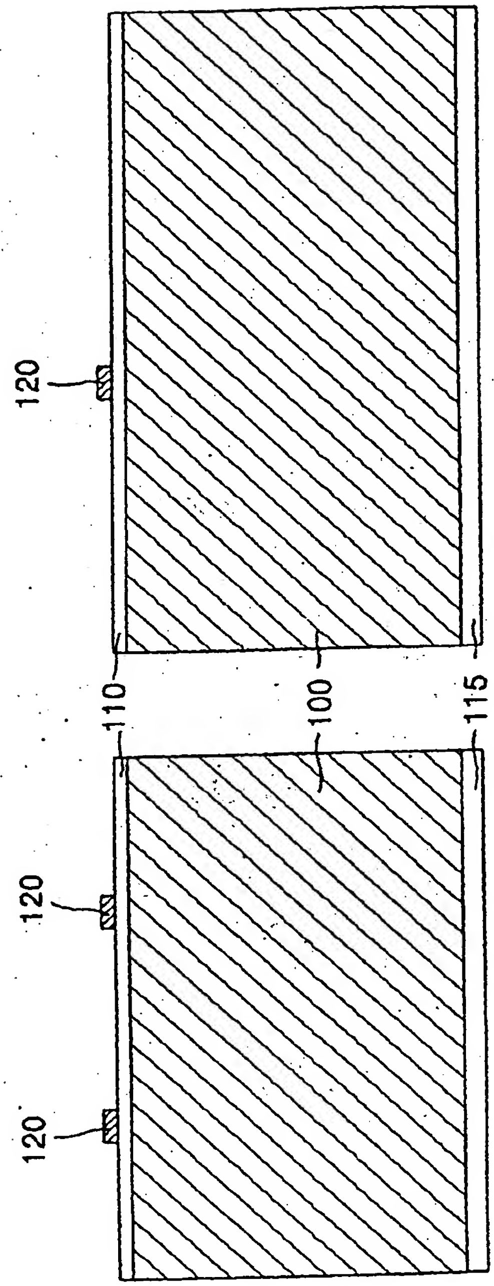

FIG. 15

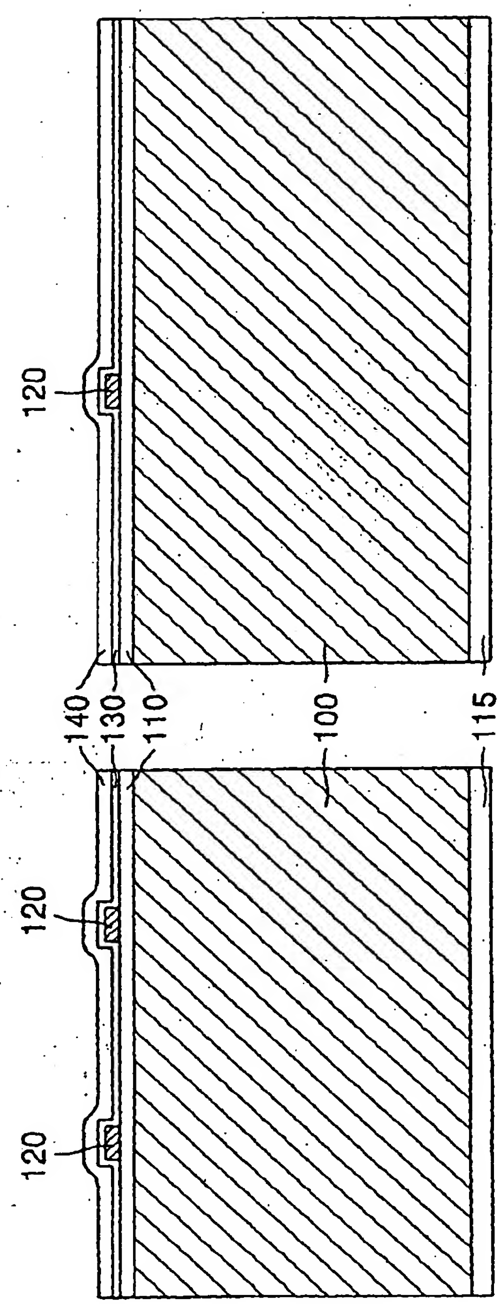
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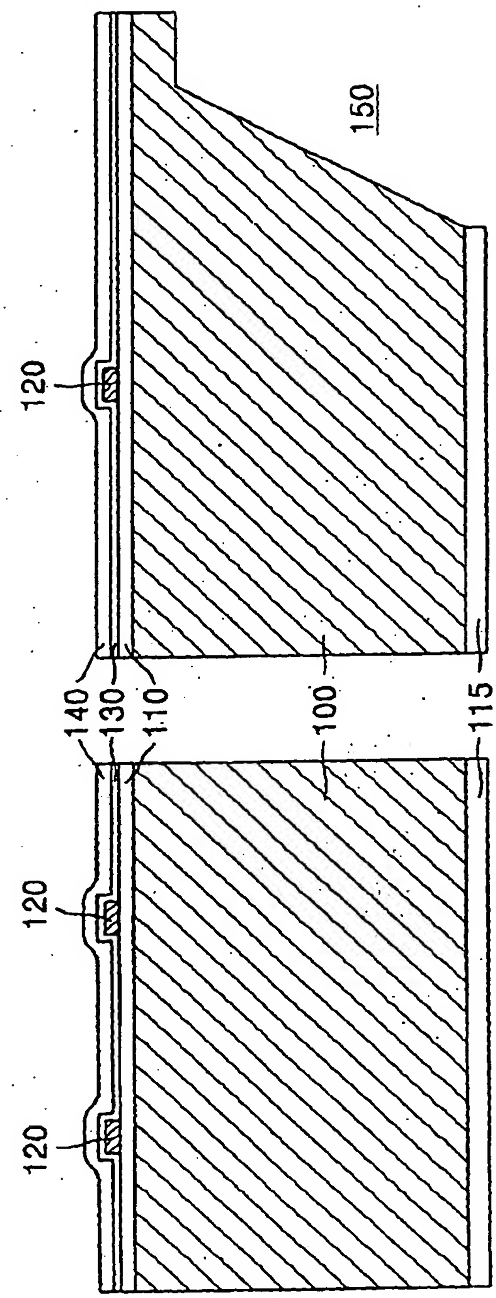
FIG. 16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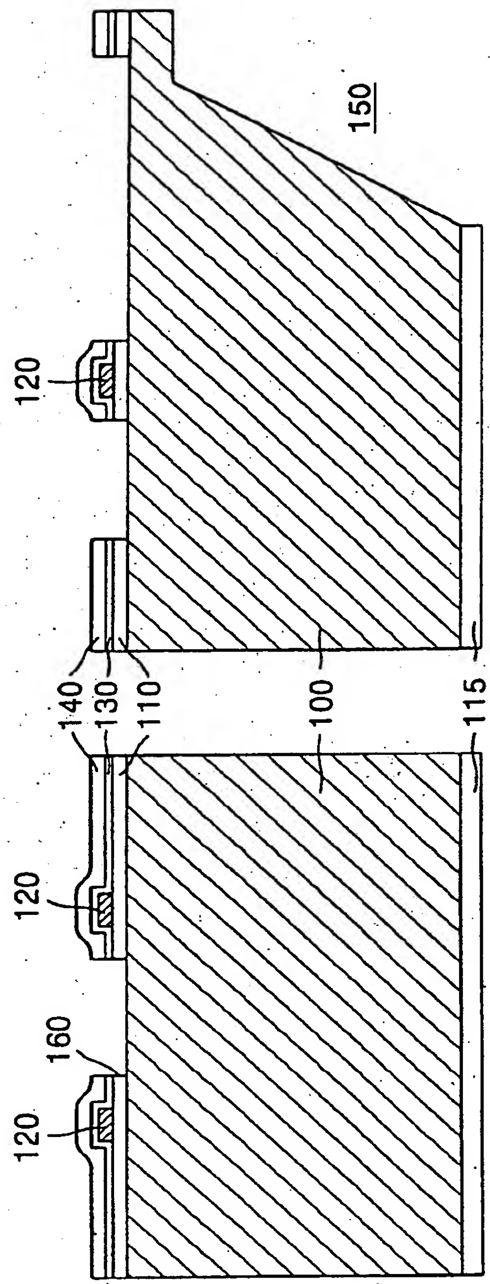
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FIG. 17

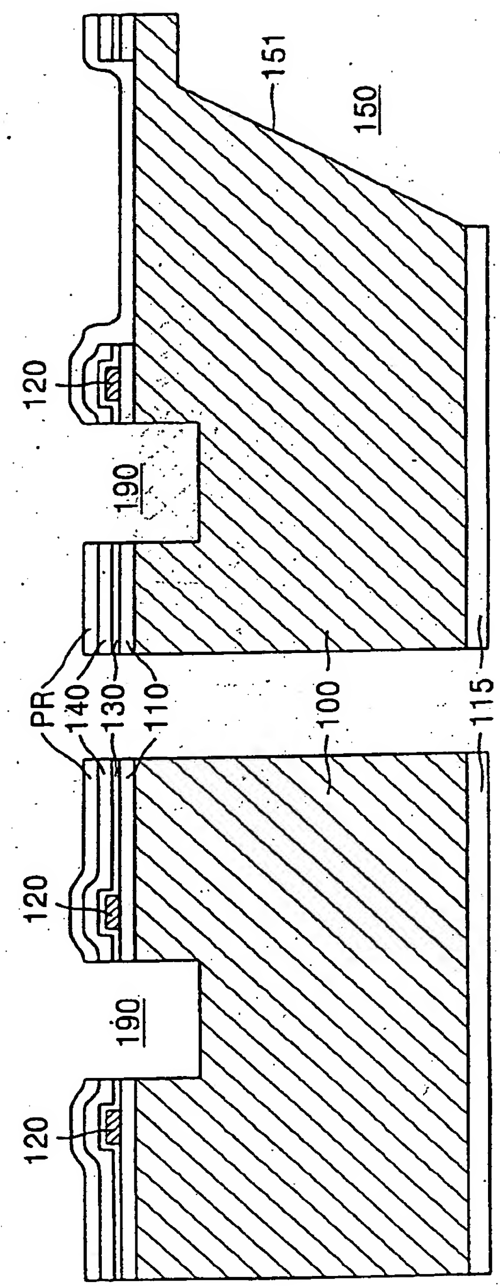
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FIG. 18

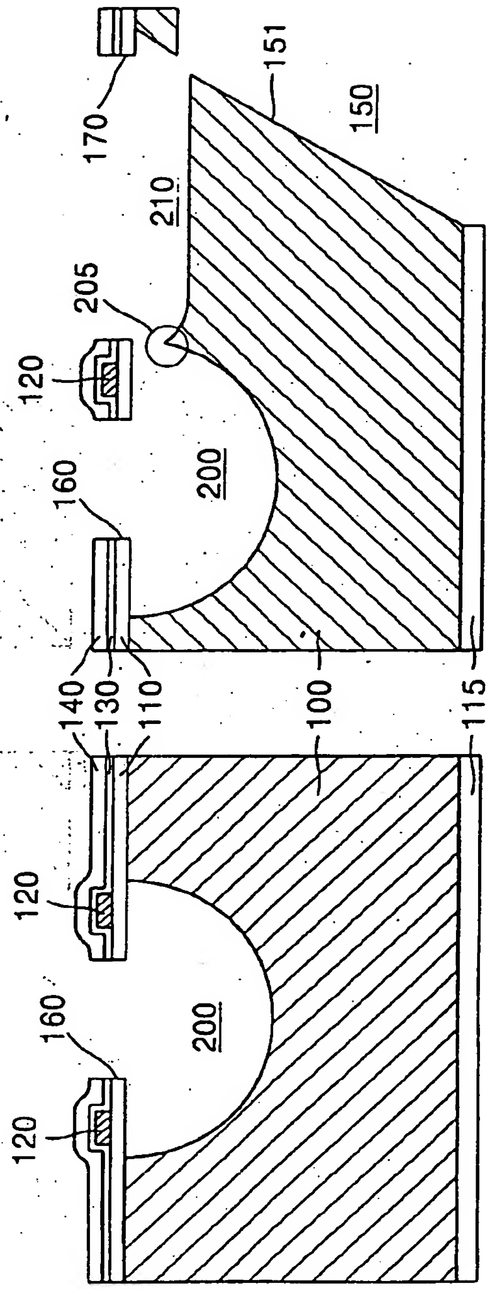
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FIG. 19

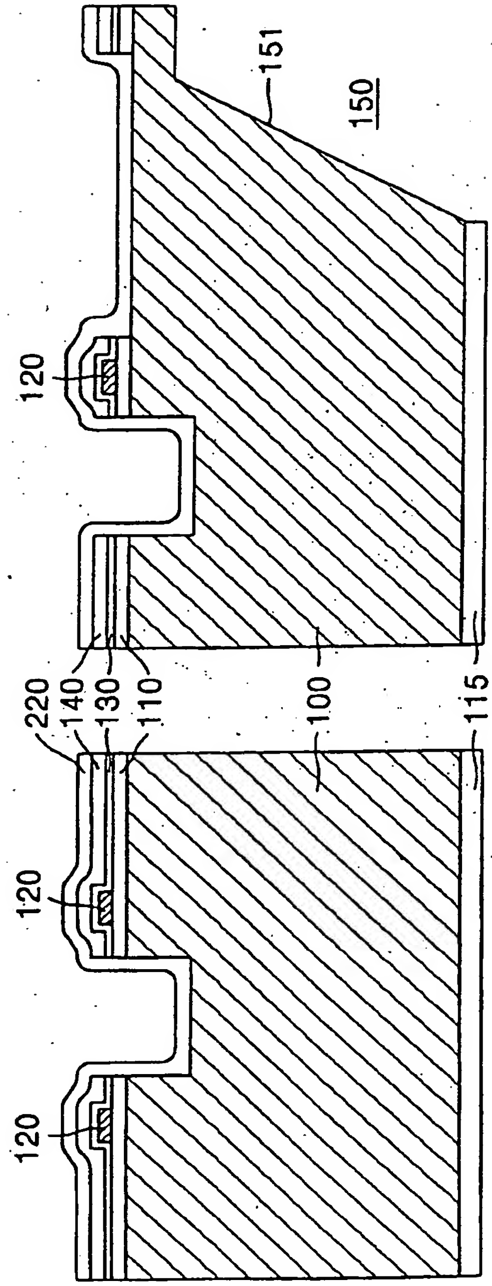
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FIG. 20

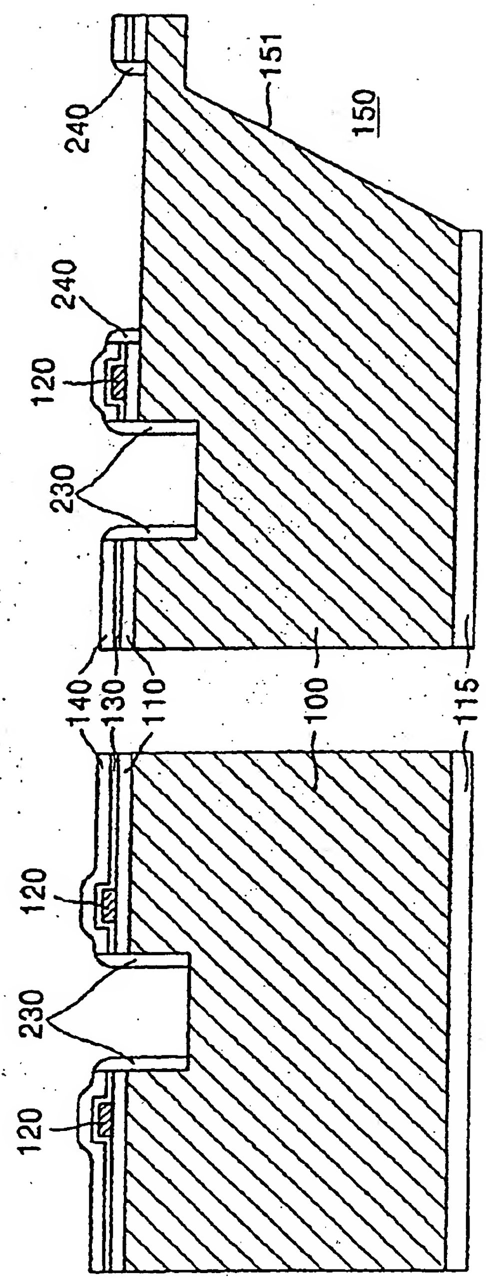
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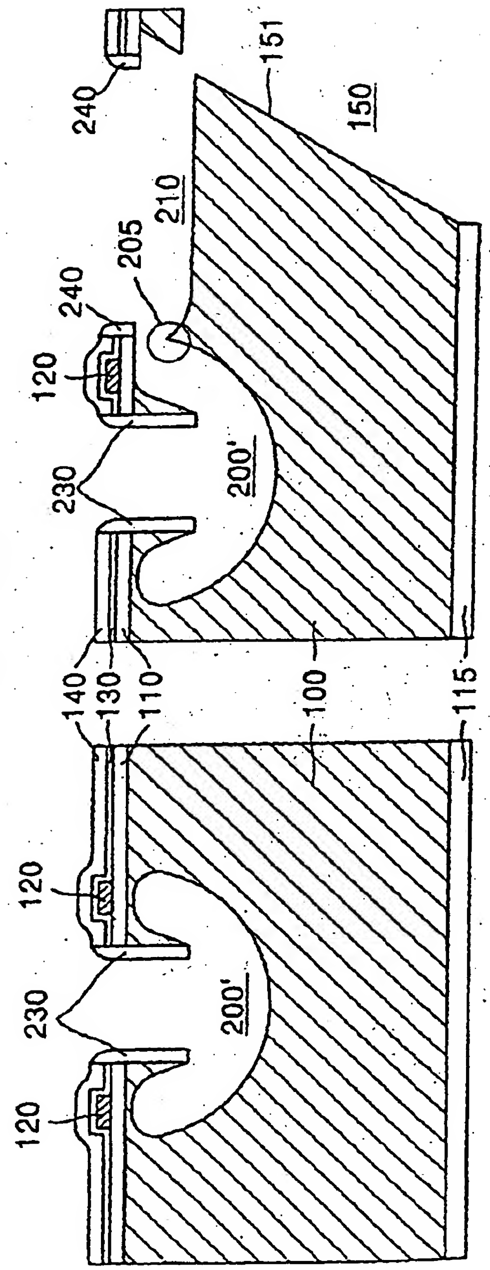
FIG. 21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200'
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FIG. 22

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 3716

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 July 2001	Bardet, M

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& : member of the same patent family, corresponding document

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 3716

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 July 2001	Bardet, M

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X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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